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ACHIEVING A SYSTEM OPERATIONAL AVAILABILITY REQUIREMENT (ASOAR) MODEL

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CECOM

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MEMORANDUM FOR DIRECTOR Defense Logistics Studies
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SUBJECT: Replacement Pages for Achieving a System Operational Availability Requirement (ASOAP) Model Documentations

1. Reference is made to the three documents submitted on ASOAR model on 28 Sep 1992.

2. Enclosed are the replacement cover sheets to two of these documents. Encl 1 is the cover sheet for the Methodology Paper, Report Number CECOM-TR-92-6. Encl 2 is the cover sheet for the Users' Manual, Report Number CECOM-TR-92-7. Please remove the old cover sheet and place these enclosed cover sheets in their corresponding documents.

3. Encl 3 is a completely new document of the ASOAR general paper, Report Number CECOM-TR-92-8. Besides containing a new cover sheet, some minor grammatical corrections were incorporated into the report. Please replace the previous CECOM-TR-92-8 submission with the enclosed documentation.

4. Point of contact for this correspondence is Christine Shin, DSN 992-4684.

5. COCOM Bottom Line: THE SOLDIER

Lawrence A. Smith

3 Encls

for EDWARD C. THOMAS
Director, Program Analysis
and Evaluation

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Achieving a System Operational Availability Requirement (ASOAR) model is a macro-analysis tool. It is basically used for an early-on Logistics Support Analysis (LSA) and macro-level Reliability, Availability and Maintainability (RAM) analysis. ASOAR can determine whether a weapon system operational availability (Ao) requirement is attainable. If attainable, ASOAR estimates optimal end item operational availabilities from the system requirement.

As an early-on LSA tool, ASOAR requires only system and end item level input data, not Line Replaceable Unit (LRU) input data. ASOAR usage provides concepts for major logistics support savings in attaining a system operational availability requirement. It outputs cost effective logistics downtimes and LRU order fill rates at the most forward level of supply support for each end item and the system. It also outputs optimal end item Ao goals usable as the Ao input to an end item sparing to availability model or an end item maintenance concept optimization model.

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19. ABSTRACT (Continued)

As a macro-level RAM analysis tool, ASOAR can aid in the selection of a system Ao requirement. The cost effective logistics downtime outputs in achieving Ao goals can improve RAM Rational analyses. It can output the effective system reliability and maintainability based on the weapon system reliability block diagram configuration design. ASOAR also outputs the effective reliability of redundant end item configurations relative to attaining its cost effective end item Ao.

This paper contains information about the ASOAR model Version 3.0 outputs and inputs, equipment configurations and support concept handled by ASOAR, and potential applications for the ASOAR model. Also, two different system supportability application examples are discussed.

ACHIEVING A SYSTEM OPERATIONAL AVAILABILITY REQUIREMENT (ASOAR) MODEL

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INTRODUCTION:

ASOAR is an acronym for Achieving a System Operational Availability Requirement. The ASOAR model is a new macro-analysis tool that estimates optimal end item operational availabilities from the system requirement. A system operational availability (Ao) requirement is a quantitative expression of user need. Ao represents the probability that an item will be in an operable or committable condition at any random point in calendar time.

This paper contains information about model outputs and inputs, equipment configurations and support concepts handled by ASOAR, and potential applications for the ASOAR model. Also, two different system supportability application examples are discussed; one in communications availability and the other in operational availability. The paper concludes with a discussion of model verification and documentation.

Prior to presenting details about the ASOAR model, it is important to discuss the equipment levels of indenture for consistent terminology. See Figure 1 to picture the hierarchy of equipment indenture levels.

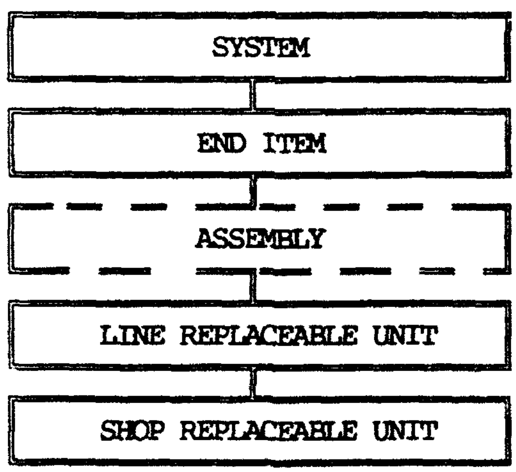

Figure 1: Equipment Levels of Indenture

The highest equipment level of indenture is the system level. The system represents the weapon system or communications system. The system is composed of end items which represents the next lower level of indenture. These end items are primary items directly purchased from a contractor or manufacturer, and are often provided as government furnished equipment to the system. End items are comprised of assemblies which represent the next lower level of indenture. These assemblies may or may not be Line Replaceable Units (LRUs) depending on whether the assembly is removed and replaced when the end item fails. An LRU is a secondary item often spared forward and is used to restore an end item if the end item goes down. Similarly, LRUs are potentially repaired by Shop Replaceable Units (SRUs) which represent the lowest equipment level of indenture in this paper. The repair of an LRU causes the LRU to be placed back into stockage at the support level where maintenance occurred.

MODEL OUTPUTS AND INPUTS:

The basic ASOAR output tells whether the system Ao is achievable. If attainable, ASOAR will output the approximate optimal Ao of each end item within the system. When similar end items are configured redundantly, the ASOAR model will output both the Ao of the redundant configuration and the individual end item Ao.

As a system level output, the system Ao goal reflects the inputted system operational availability. The adjusted system Ao goal output shows whether scheduled maintenance or periodic downtime adjustments caused the inputted Ao goal to increase. The outputted end item availability product is the computed operational availability of the outputted results. The ASOAR model will cease computation when the difference between the product of the operational availabilities of all end item configurations and the adjusted Ao goal are within a tolerance of 0.0001.

One of the key system level outputs of the ASOAR model is the effective reliability of the system. In ASOAR Version 3, the reliability output variable reflects the inputted reliability variable utilized in the application. The model is flexible to use either Mean Time Between Failure (MTBF), Mean Calendar Time Between Failure (MCTBF), or Failure Factor to describe reliability. The system reliability is dependent on the reliability inputs for each end item and the inputted system reliability block diagram configuration of the end items within the system.

The MTBF of a system or end item represents the design reliability of the equipment. MTBF is expressed in terms of operating hours per failure. The MTBF requirement of an end item can often be found in the equipment's specification document. The MCTBF of equipment is the reliability requirement expressed in calendar time as opposed to operating hours. The ASOAR model internally computes reliability in terms of MCTBF because Ao represents the probability of equipment being up at any random point in calendar time. The Failure Factor of equipment is expressed in terms of failures per 100 end items per year. Maintenance engineers sometimes express reliability in these terms.

Another key system level output of the ASOAR model is the effective maintainability of the system. The model is flexible to use either Mean Time To Repair (MTTR) or Mean Time to Restore (MTR) to describe maintainability. System maintainability is equal to the percentage of each end item's effective contribution to system failure multiplied by its maintainability.

MTTR is the design maintainability of the equipment which assumes that all logistics support for the equipment is perfect. The MTTR requirement of an end item can often be found in the equipment's specification document. MTR is the experienced maintainability of the equipment assuming that LRU spares are always available. MTR depends on the equipment's MTTR plus any additional forward support level downtime due to the extra time it takes to obtain spare LRUs from storage, not always having appropriately skilled personnel available, not always having functioning test measurement and diagnostic tools with the equipment, or lack of complete or efficient forward level repair manuals.

The logistics downtimes computed for the system and all of its end items to achieve their respective Ao are outputs of the ASOAR model. The Mean Logistics Downtime (MLDT) covers equipment downtime due to LRU spares not always being available forward with the equipment. The Average Logistics Downtime (ALDT) includes all equipment downtime factors except for the design maintainability. ASOAR Version 3 will output the MLDT when MTR is utilized as an input variable or output ALDT when MTTR is utilized as an input variable.

The LRU order fill rate of the system and all of its end items to achieve their respective Ao are outputs of the ASOAR model. The LRU order fill rate for the equipment specifies the percentage of time that appropriate LRUs must be on-hand at the forward level of stockage to restore the system. This is a special type of stock availability at the forward support level which accounts for the need of an LRU spare only when it repairs a system failure causing downtime. When the appropriate LRU is not on-hand at the forward level of supply, it must be obtained in order to restore the equipment. Without redundancy, MLDT is equal to the percentage of time that appropriate LRU spares are not on-hand to restore the equipment multiplied by the Mean Time to Obtain (MTTO) those LRUs.

A typical listing of system level output variables is shown in Figure 2. Their units of measurement are noted in parentheses.

System Operational Availability Goal (percentage)

Adjusted Operational Availability Goal (percentage)

End Item Operational Availability Product (percentage)

Mean Time Between Failures (hours)

Mean Time to Repair (hours)

Average Logistics Downtime (hours)

Order Fill Rate of LRUs (percentage)

Figure 2: Typical System Level Outputs

Some end item level outputs have been already covered. However, the effective reliability, effective logistics downtime, and MTTO outputs of each end item require more discussion.

When multiple similar end items are configured within the system or end item level spares are utilized in lieu of LRUs to repair the system, the effective reliability is calculated. Otherwise, the effective reliability is just the inputted reliability. The effective reliability of a configuration of redundant end items is computed by ASOAR relative to attaining the optimal end item Ao. With redundancy, the effective reliability of a configuration is impacted by its logistics support. The end item Ao permits a certain amount of logistics downtime to occur. The larger the downtime, the greater the likelihood that the redundancy is not repaired before additional failures occur. These additional failures may cause the system to fail which impacts the redundant configuration's reliability.

The effective logistics downtime output is also impacted by a redundant configuration. For example, in a configuration with one redundant end item, two end item failures prior to the first failure being restored will cause system downtime. Repair of the first failure will cause the system to be restored. The time between occurrence of the second failure and repair of the first failure yields less system downtime per redundant configuration failure.

The Mean Time to Obtain (MTTO) LRU spares for the end items may be inputted directly or calculated from many supply and maintenance inputs describing the logistics support associated to each end item. Supply input variables provide information on the supply support concept, order and ship times, and stock availabilities at the higher levels of support. Maintenance input variables provide information on the maintenance concept, repair turnaround times, and repair percentages of the LRUs at different support levels.

A typical listing of end item output variables is shown in Figure 3. The words noted in parentheses do not appear on the actual output.

(End) Item Name

(End) Item MTBF

Effective MTBF (of Configuration)

(End Item) MTTR

MTTO (LRU Spares)

Effective ALDT (of Configuration)

Ao (of Configuration)

Ao of 1 (End Item)

(LRU Order) Fill Rate

Figure 3: Typical End Item Level Outputs

At the system level, the ASOAR model requires an input for the system Ao desired or required. Also, the reliability block diagram configuration of the end items within the system needs to be inputted.

As end item level attributes, the ASOAR model requires inputs about each end item's reliability, maintainability and cost. The terminology utilized in reliability and maintainability inputs and corresponding outputs are easily selected by the model user. The utilized end item cost is computed from the inputted cost of a single end item minus the inputted cost of any very high cost/low failure rate assemblies within the end item. This cost adjustment improves the accuracy of model optimization results. Since the optimum allocation of operational availability is driven by the relative cost to failure rate ratios of end items comprising the system, the cost adjustment reduces inaccuracies by not incorporating assemblies with very little chance to be economically stocked forward.

The key logistics input is the mean time to obtain LRU spares. If MTTO is to be computed, then supply and maintenance inputs are utilized instead.

EQUIPMENT CONFIGURATION AND SUPPORT CONCEPTS HANDLED:

The basic ASOAR methodology optimizes the allocation of the system Ao to the end items when the system consists of different individual end items in a serial configuration, the system is maintained by LRUs at the operating or Organizational (ORG) level, and no scheduled maintenance or periodic downtime exists. Computational equivalency adjustments are applied when end item commonality or redundant equipment configurations exist, when scheduled maintenance or periodic downtime applies to the equipment, when the most forward level of supply support is Direct Support (DS) or General Support (GS), and when end item spares are permitted at the most forward level of supply support. All ASOAR computational equations and their derivation are explained in the "ASOAR Model Version 3 Methodology" paper.

The ASOAR model utilizes special cases to handle these computational equivalency adjustments. The ten special cases utilized by the ASOAR model are listed in Figure 4.

1. Serially Configured Common End Items
2. Hot Standby Redundant End Items
3. Cold Standby Redundancy or End Item Spares With System
4. Degradational Redundancy or Capacity Availability
5. System Scheduled Maintenance or Periodic Startup Causing Downtime
6. End Items Scheduled Maintenance or Periodic Startup Causing System Downtime
7. Multiple Systems Restored with LRU Spares at ORG Level
8. Systems Restored with LRUs Stocked Forward at DS Level
9. Systems Restored with End Item and LRUs Stocked Forward at DS Level
10. Systems Restored with End Item Spares at DS Level and LRUs Stocked Forward at GS Level

Figure 4: Equipment Configurations and Support Concepts Special Cases

The first four cases cover equipment configuration adjustments. Case 1 handles common end items which is having more than a quantity of one of the same end item in series. LRU spares placed forward can be used to repair any of the similar end items. Case 2 handles hot standby redundant end items. Case 3 covers cold standby redundant end items or end item spares at the operating level. The difference between hot and cold standby redundant items is that the hot items in redundancy are operating where the cold items in redundancy are not operating. Cold standby redundancy accrues extra downtime to switch over to redundant end items, but does not accrue extra failures from additional operating hours. Case 4 examines degradational redundancy or capacity availability. With degradational redundancy, the system does not have to be fully up or fully down. Each potential state can be represented by some inputted percent of upness.

Cases 5 and 6 represent downtime adjustments to operational availability. Case 5 covers scheduled maintenance downtime at the system level. It can also account for periodic teardown and set-up of the system. Case 6 covers scheduled maintenance downtime at the end item level. If necessary, it can also be used to account for unscheduled downtime from a hot standby redundancy because downtime to switch over to the operating redundant item is not automatically covered in Case 2. When using the cold standby redundant mode of Case 3, ASOAR automatically asks for the downtime input to switch over to the non-operating redundant item.

Cases 7 through 10 examine centralized forward support adjustments. Case 7 deals with multiple systems restored with LRU spares at the operating level. Cases 8 through 10 are for systems without operating level spares. This centralized supply support concept could be accomplished using contact maintenance team support, having direct exchange support, or by evacuating the failed system to Direct Support (DS). Case 8 covers systems restored with LRU spares stocked forward at the DS level. Cases 9 and 10 consider system restoral primarily with the use of end item spares at DS level. These end items spares are called floats. Case 9 covers systems restored with end item floats and LRU spares at DS. Case 10 covers systems restored with end item floats at DS and LRU spares stocked forward at the General Support level.

MODEL USEFULNESS AND APPLICATION:

ASOAR can be a very useful model to the military user community. ASOAR is a macro-analysis tool that estimates optimal end item operational availabilities from the system requirement. Sensitivity analysis can also be performed on the system Ao to aid in the selection of a requirement.

The ASOAR model is also an earliest-on logistics support analysis tool because it requires system and end item level input data without requiring LRU input data. ASOAR can determine whether the system Ao is attainable for an inputted logistics support concept. When achievable, cost effective logistics downtimes and LRU order fill rates at the most forward level of supply support are determined for each end item comprising the system. From a broad perspective, this helps to determine the degree of logistics supportability necessary to achieve each operational availability.

ASOAR is an ideal tool for Reliability, Availability and Maintainability (RAM) rationale analysis. It can aid in the selection of a system Ao requirement. The effective system reliability and maintainability are determined from end item reliability and maintainability input data and the system's reliability block diagram configuration of end items. The optimum ALDTs for the system and each type of end item within the system are outputs of the ASOAR model. This eliminates the need to guess at ALDT values to perform RAM rationale analysis and improves analysis accuracy.

ASOAR can be a very useful model to the materiel developer community. It can be utilized to analyze system design sensitivity to reliability block diagram configurations. ASOAR determines the effective system reliability and maintainability, and the effective reliability and logistics downtime of redundant end item configurations relative to attaining its computed cost effective Ao. Hot standby, cold standby and degradational redundancies of similar end items are handled.

ASOAR also aids weapon system logistics support optimization. First, it provides a macro-level analysis about inputted support concepts. The end item order fill rates computed yield a generalized feel about the costliness of spares needed to attain the system Ao requirement. The cost effective end item Ao outputs of the ASOAR model feed sparing and maintenance optimization models.

Figure 5 illustrates how the application of the ASOAR model used together with a sparing optimization model can optimize LRU and SRU inventories to meet the weapon system Ao requirement. Also, ASOAR used together with a maintenance allocation optimization model can optimize maintenance concepts to achieve the weapon system Ao requirement. ASOAR permits the optimization of system supply and maintenance allocation to system requirements because it outputs end item Ao requirements that can optimally achieve the system Ao requirement. The end item Ao outputs then become inputs to maintenance optimization and supply support optimization models. When multiple similar end items are configured, the output of the Ao for one end item is utilized as the input to the end item optimization models. As LRU and SRU data becomes available for an end item, the optimization model for sparing, such as SESAME, can determine the least cost sparing mix to achieve the inputted end item Ao requirement. Also, an optimization model for maintenance allocation, such as OSAMM, can determine the least cost maintenance concepts for the end item to achieve its inputted Ao.

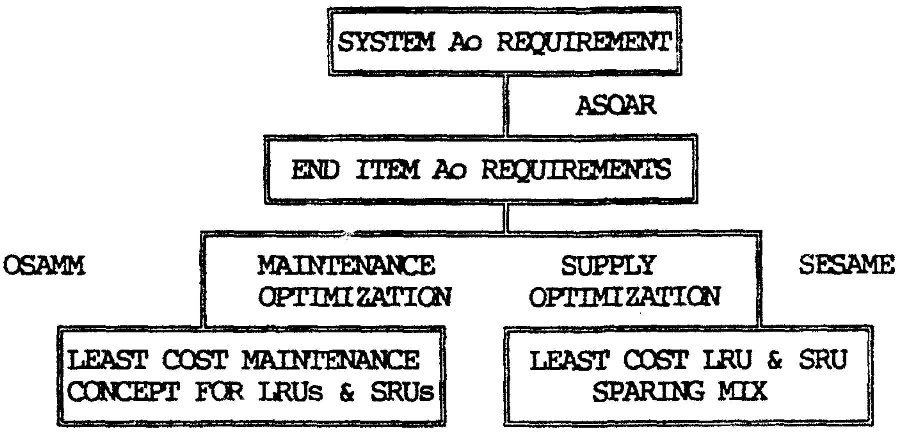

Figure 5: Optimization of Lower Indentured Items to Achieve the System Requirement

ASOAR can be useful to both the materiel developer and user communities by optimally allocating the weapon system operational readiness requirement to desired readiness rates for each major end item comprising the weapon system. Operational readiness rates of fielded items are essentially an approximation of the operational availability determined from data collection. Rules defining system downtime and uptime for operational readiness purposes may possibly vary from the use of all calendar time uptime and downtime that determines Ao.

The ASOAR model is also usable for optimizing communications availability support of non-complex communications networks. The model is limited to non-complex communication networks because it does not compute the percent of upness associated to degradational redundant states. It requires the percent of upness to these states to be an input. Also, ASOAR does not handle alternative means of communication because dissimilar end item redundancy is not handled.

An example with a hypothetical Regency Net system is used to explain the model's usefulness in optimizing to a communications availability. The system of Regency Net terminals may be configured with 7 redundant Injection Terminals (IT), 2 redundant Super Cluster Controllers (SCC), 2 redundant Cluster Controllers (CC), a Force Terminal (FT), and a Team Terminal (TT). Except for the TT, all terminals have identical reliabilities and cost. The TT is the most forward terminal and smaller than all the terminals causing it to be almost twice as reliable at five times less cost. A system Ao goal of 93% was used to communicate from the IT all the way to the TT.

The results obtained from using ASOAR logically showed that no spare LRUs were necessary at any of the 7 highly redundant ITs. Only a 39% order fill rate of appropriate LRU spares was needed at the SSC and CC redundant terminals. The FT and TT were the serial configured terminals and they both required high LRU order fill rates of 94% and 98% respectively. If all terminals were spared similarly, an 88% LRU order fill rate would be necessary at every terminal to achieve the communications availability of 93%. By doing system sparing optimally, 7 terminals did not require any spares, 4 terminals required just a 39% order fill rate of LRU spares, and only 2 terminals required more than the 88% LRU order fill rate. This represents a large supportability savings which could not be achievable without using ASOAR.

The ASOAR model was successfully applied to a sustainability evaluation of the Corp/Theater ADP Service Center II (CTASC II) to a system operational availabilty goal. The CTASC II system configuration had many redundant types of end items in it. Just 4 end items were listed as serial and they were serial components within the computer processing unit, serial components within the communications equipment, the power supply, and the nine-track tape unit.

The results of the CTASC II Sustainability Study using ASOAR showed that only the LRUs of the serially configured end items needed to be spared with the terminals. The product of end item availabilities of the serial items from ASOAR was utilized as the Ao input in SESAME to optimize their LRU sparing mix. Also, by using ASOAR, it was determined that one of the logistic support alternatives was risky. Without spares placed forward with the CTASC II terminals, the contractor regional support center alternative cannot exceed twelve hours to restore the CTASC II terminals or the system Ao requirement of 96% could not be achievable.

MODEL VERIFICATION AND DOCUMENTATION:

The ASOAR model was developed to respond to a challenge specified within the Secretary of Defense Guidance of March 1982.[1] The unclassified excerpt states "Our objective is to size and fund peacetime operating stock secondary item inventory to support programmed weapon systems availability rates and operating tempos. Since analytical methodologies to achieve this do not now exist, the Services will develop and institute, by the end of FY85, the ability to size weapon system initial and replenishment secondary item inventories to meet explicit weapon system availability and operating tempo objectives."

Model and methodology verification and validation started with a comparison of the ASOAR basic methodology to results from SESAME.[2] Using the same curve parameter, SESAME optimized Ao results for each end item. Using the calculated SESAME system Ao, results were found to be somewhat close to the ASOAR prorated Ao to each end item. However, if LRUs are modeled like end items in ASOAR, the resulting availability of LRUs will be inaccurate.

Each special case of ASOAR was successfully evaluated against its manual computations. The inputting order of the multiple special cases was also varied. Cases 1 through 6 results were found to be independent of the input sequence. However, Cases 1 through 6 must be inputted prior to Cases 7 through 10 for correct results. Cases 7 through 10 compute centralized forward support adjustments.

ASOAR Version 2 was limitedly distributed within the Army from October through December 1990. After this distribution, mistakes were found in the methodology used for Cases 7 through 10. These errors have been corrected in ASOAR Version 3. Also, ASOAR Version 2 required MCTBF and MTR inputs and displayed the MLDT output. Although internal computations with ASOAR are based on these variables, their terminology is not often familiar to model users. ASOAR Version 3 improved model flexibility to optionally permit inputs and outputs to also be in terms of failure factors or MTBF, MTTR and ALDT.

The ASOAR Model Methodology documentation for Version 3 explains and derives all the ASOAR basic equations and mathematically describes all special case computational adjustments.[3] The ASOAR User's Manual describes how to use the model and explains and lists all the input and output variables.[4] Exercises included in the User's Manual take the user through sample runs covering the Mean Time to Obtain LRUs and the 10 special cases.

ASOAR is a deterministic model. It operates on a Zenith personal computer or compatible with a math co-processor and the ASOAR software. ASOAR documentation and a disk containing the executable code of the ASOAR model may be obtained by contacting the author.

ACKNOWLEDGMENT:

The following individuals have been responsible for developing the ASOAR model. The author wishes to express his gratitude to Jesse Williams, Gerald Gerstel, Anthony DiGregorio and Christine Shin for their dedication in developing and testing various versions of ASOAR computer programs.

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1. DoD Defense Guidance, FY84-83, March 22, 1982, p. 75, para. b.

2. Jesse Williams, "Development and Test of the ASOAR Model," US Army Electronics Research and Development Command, August 30, 1984.

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4. Christine Shin, "ASOAR Model Version 3 User's Manual," US Army Communications-Electronics Command, July 1992.

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INTRODUCTION STATEMENT

Bernard Price is currently Chief of the Systems Analysis Division within the US Army Communications-Electronics Command. His presentation will cover the Achieving a System Operational Availability Requirement Model called ASOAR. Mr. Price is briefing the ASOAR model because it is a new, unique tool for analyzing weapon system reliability, availability and maintainability and analyzing weapon system logistics supportability.